Active/Passive Microwave System with Deployable Mesh Antenna for Spaceborne Ocean Salinity Measurements

William J. Wilson, Eni G. Njoku, Simon H. Yueh
Jet Propulsion Laboratory, California Institute of Technology
4800 Oak Grove Drive, Pasadena, CA 91109
Tel: (818) 354-5699, FAX: (818) 393-4683, E-mail: william.j.wilson@jpl.nasa.gov

Abstract—A concept has been studied for remote sensing of sea surface salinity from space using a large deployable mesh antenna system. The antenna has a 6-m-diameter offset-fed parabolic reflector with multichannel feedhorns and radiometers and a radar, operating at L and S bands. The entire system rotates about the nadir axis, providing a conical scan across a 900km wide swath at a spatial resolution of about 40 km from a 600-km orbit altitude. The study includes evaluation of deployable mesh antennas and preferred antenna, spacecraft, and launch vehicle configurations. Designs for compact, lightweight feedhorns and radiometer/radar electronics were also developed.

1. Introduction

This paper describes a study of a large mesh antenna system with active and passive microwave sensors for high resolution real-aperture sensing of the Earth surface. The objective is to apply the technology of large, lightweight mesh antennas to the remote sensing of land, ocean and cryospheric phenomena where low frequencies and/or high spatial resolution are required. Sea surface salinity and soil moisture are primary applications of this technology since they require low frequency observations at 1.4 GHz and spaceborne measurements of these parameters do not currently exist. For convenience, the instrument concept has been named OSIRIS (Ocean-salinity Soil-moisture Integrated Radiometer-radar Imaging System). However, the technology is potentially applicable to other remote sensing applications that can benefit from high spatial resolution microwave observations using frequencies as high as 37 GHz, such as ocean winds, precipitation, sea ice, and snow. Such observations are needed for detailed modeling and forecasting of the Earth's hydrologic cycle.

The key technology is the lightweight mesh antenna. Deployable mesh antennas are a mature technology with extensive flight heritage in space telecommunications. Recently, 12-m-diameter antennas have been developed and space qualified in the commercial sector, and are planned for launch on geostationary communication satellites in 2000 [1]. The TRW Astro 12-m perimeter-truss antenna has been tentatively selected for this project, and is shown in Fig. 1.

Fig. 1 TRW Astro 12-m perimeter-truss antenna deployed in the test facility. (Courtesy of TRW Astro)

2. Science Requirements

Science requirements for sea surface salinity (SSS) observations from space are outlined in reports of the Salinity Sea Ice Working Group (SSIWG) [2]. The SSS requirements are used as the basis for the system design described in this paper. A SSS measurement accuracy of 0.2 psu ('practical salinity units' or parts per thousand) at a 1-week, 100-km time-space scale is the primary goal. These requirements can be met by a sensor with a footprint resolution of 40–60 km, an accuracy per footprint of ~0.6 psu, and a wide swath for providing global coverage in 2–3 days. Averaging the data on a 1-week, 100-km grid reduces the measurement noise error, and provides an accuracy of ~0.2 psu. Averaging on a 1-month, 200-km grid provides a potential accuracy of 0.05 psu. The technique for retrieving SSS from microwave measurements, including choice of radiometer and radar channels, polarizations, and incidence angle, and results of detailed simulations of the error sources and their impact on SSS retrievability, are discussed in [3].

The SSS accuracy requirement of 0.2 psu leads to requirements for radiometric precision of 0.1 K and calibration stability of 0.2 K, radar precision and stability of 0.2 dB, incidence angle of >40°, and a conical-scan with the incidence angle fixed across the swath. A beam-pointing knowledge of 0.1° is required to keep the corresponding brightness temperature uncertainty to less than 0.15 K. Pointing control to within about half a 3-dB-beamwidth is necessary for accurate geolocation. A polar, sun-synchronous orbit with pre-dawn equator crossing (~6am) is required to obtain global coverage and to minimize Faraday rotation, and is advantageous from the point of view of thermal stability of the instrument and utilization of solar power. The above requirements are addressed in more detail in [3].

4. System Characteristics

The baseline system adopted for our study uses a 6-m-diameter conically scanning antenna as shown in Fig. 2.

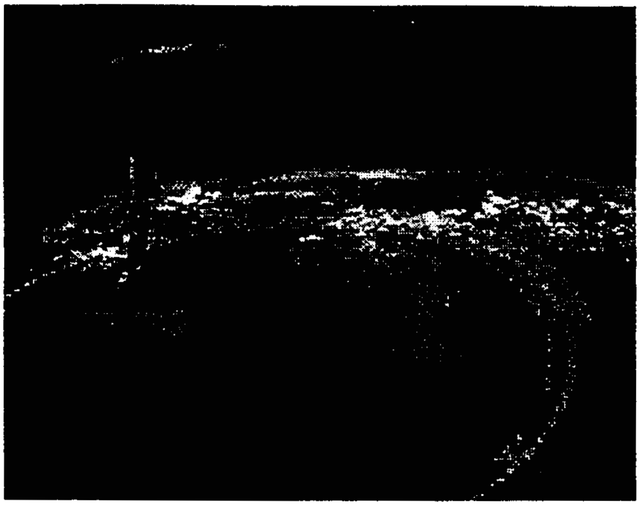

Fig. 2 Artist's concept of OSIRIS

The key system characteristics are summarized in Table 1. The antenna system is a rotating, offset-fed, parabolic-mesh reflector, with two identical multichannel feedhorns, which feed the L and S-band radiometers and the L-band radar. The two feedhorns provide separate beams that give overlapping contiguous footprints at the surface, and allow the antenna system to rotate at 6 rpm which is half as fast as would be necessary with a single beam. The combined antenna and feed system rotates about the vertical axis, with antenna beams at an incidence angle of 40°. As the spacecraft moves, the 3-dB antenna footprints provide overlap along and across track in a helical coverage pattern. At an orbit altitude of 600 km, the 6-m antenna provides ~40-km spatial resolution, and a swath width of 900 km.

4. Configuration

Mission cost constraints require that the stowed volume of the spacecraft and payload fit within a Taurus-class or smaller launch vehicle. The spinning antenna requires a spacecraft that either rotates with the antenna as a rigid body or is 3-axis stabilized with a spinning platform on which the antenna is mounted.

Candidate antenna, spacecraft and launch vehicle configurations have been studied to evaluate the stowed volume, mass, deployment and attitude control requirements of the system. Fig. 3 shows one possible configuration of the stowed and deployed antenna system. The configuration shown is for a 6-m TRW Astro antenna, a TRW SSTI Core spacecraft, and a Taurus launch vehicle with 92-inch fairing.

Table 1. Key baseline system characteristics

Radiometer frequencies	1.41 and 2.69 GHz
Radiometer polarizations	H, V; (1.41 GHz polarimetric)
Radar frequency	1.26 GHz
Radar polarizations	VV, HH,VH, HV
Antenna type	Offset-fed, parabolic, deployable mesh reflector
Aperture diameter	6 m
Ocean Incidence angle	40°
Number of feedhorns	2 (each L/S-band, V/H-pol)
Beamwidths	2.6° (approx. equal all channels)
Antenna gain	35 dB
Beam efficiency	> 90%
Orbit type	Polar, sun-synchronous, 6am/6pm
Altitude	600 km
Spatial resolution	35 x 45 km
Swath width	900 km
Rotation rate	6 rpm
Global coverage	2-3 days
Pointing control/knowledge	1.3°/0.1° (3σ)
Radiometer NEDT per footprint	0.2 K
Radiometer absolute accuracy and stability	1 K and 0.2 K
Radar precision/stability	0.2 dB
Power	350 Watts
Data rate	25 Kbits/sec
Mass	530 kg
Launch vehicle	Taurus-class with 92" fairing
Mission duration	3 years

This configuration is illustrative but does not imply an optimized or selected system. The 92"-Taurus is capable of placing about 720 kg of payload into a 600-km sun-synchronous orbit. The configuration shown, with the antenna mounted above the spacecraft, was selected as the be best design based on simplicity of deployment, minimum attitude control system (ACS) requirements, design flexibility, and environmental impacts (e.g. solar heating, solar leakage to feedhorns, environmental momentum).

Two alternatives for the spacecraft were considered, one a rigid-body spinner with the antenna directly mounted and the other a non-spinning 3-axis stabilized bus with a

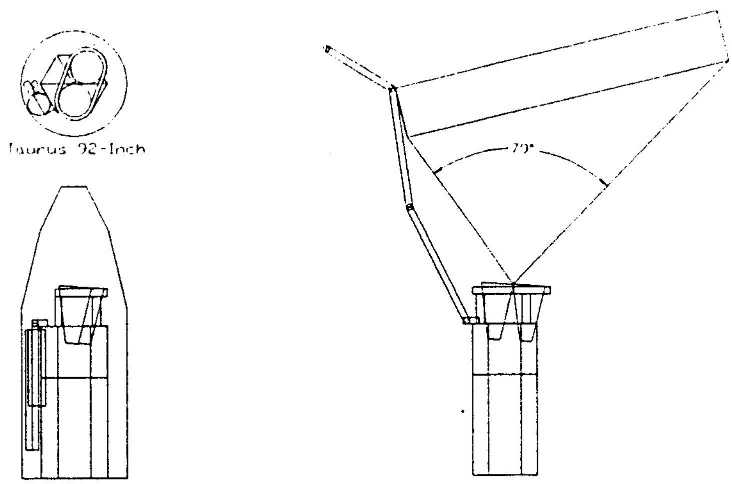

Fig. 3 Illustration of antenna and spacecraft in stowed and deployed configuration

spinning platform for the antenna. Preliminary torque and momentum analyses indicate that the system will operate best at zero momentum with a large momentum wheel to counteract the 6-rpm rotation of the spacecraft and antenna (in the rigid-spinner configuration) or antenna only (in the 3-axis-stabilized case).

5. Antenna and Electronics Design

Analyses have been done of antenna and electronics subsystems designs for the baseline OSIRIS system. The profiled or compact multi-frequency corrugated horn was found to have the most suitable symmetrical-beam performance over the large frequency range required (1.2–2.7 GHz). The beam efficiencies were calculated to be 94% and 92% at L and S band, respectively.

A radiometer and radar design with advanced space-qualified electronics was developed to obtain minimum mass, volume and power requirements. The key features of the radiometer design are to use a tuned RF MMIC radiometer with noise diode injection for calibration. A polarimetric capability is included to enable correction for the Faraday rotation. Key aspects of the radar design include a 100-W RF transmit power and 4-MHz chirp bandwidth to obtain better than 0.2 dB Kpc. The radar pulse length is 1 ms (10% duty cycle) which enables 90% of the time to be available for the radiometer integration.

6. Conclusions

This paper has provided an overview of a study of a large mesh antenna system for spaceborne active and passive microwave sensing at L and S bands. A baseline system has been defined and evaluated from the standpoints of science accuracy requirements, preferred antenna, spacecraft and launch vehicle configurations, and antenna and electronics designs. Additional studies are being performed to characterize the radiometric properties of the mesh, refine the system design, and to provide detailed simulations of the expected system performance in orbit.

Acknowledgments

This work represents one phase of research carried out at the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration. The work is funded by the NASA Instrument Incubator Program which is part of the NASA Code Y Earth Science Enterprise Office. The authors wish to acknowledge the information provided this study by Mark Thomson of TRW Astro.

References

[1] B. Miller, "Satellites free the mobile phone," *IEEE Spectrum*, vol. 35, pp. 26–35, 1998.

[2] G. Lagerloef, "Preliminary assessment of the scientific and technical merits for salinity remote sensing from satellite," *Final Report of the First Workshop, Salinity Sea Ice Working Group, La Jolla, CA, 7–8 February, 1998*, http://www.esr.org.

[3] E. Njoku, W. Wilson, S. Yueh, and Y. Rahmat-Samii, "A large-aperture microwave radiometer-scatterometer concept for ocean salinity and soil moisture sensing," *IEEE Trans. Geosci. Rem. Sens.*, (in press) (2000).